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RESEARCH ARTICLE

Assessing learning, quality and engagement in learning objects: the Learning Object Evaluation Scale for Students (LOES-S)

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Abstract Learning objects are interactive web-based tools that support the learning of specific concepts by enhancing, amplifying, and/or guiding the cognitive processes of learners. Research on the impact, effectiveness, and usefulness of learning objects is limited, partially because comprehensive, theoretically based, reliable, and valid evaluation tools are scarce, particularly in the K-12 environment. The purpose of the following study was to investigate a Learning Object Evaluation Scale for Students (LOES-S) based on three key constructs gleaned from 10 years of learning object research: learning, quality or instructional design, and engagement. Tested on over 1100 middle and secondary school students, the data generated using the LOES-S showed acceptable internal reliability, face validity, construct validity, convergent validity and predictive validity.

Keywords Evaluate · Assess · Quality · Scale · Secondary school · Middle school · Learning object

Overview

Learning objects are operationally defined in this study as interactive web-based tools that support the learning of specific concepts by enhancing, amplifying, and/or guiding the cognitive processes of learners. Many learning objects offer visual aids to help guide. For example, in mathematics students could be asked to enter in various functions to see how they appear on a graph. In essence, they are testing various "what-if" scenarios (see http://www.shodor.org/interactivate/activities/FunctionFlyer/). In science, a number of learning objects provide a rich visual context, such as understanding how specific functions of the body work (see http://www.sickkids.ca/childphysiology/).

The design, development, reuse, accessibility, and use of learning objects has been examined in some detail for almost 10 years (Kay and Knaack 2007a), however, research

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on the impact, effectiveness, and usefulness of learning objects is limited (Kay and Knaack 2005; Nurmi and Jaakkola 2005, 2006a, b; Sosteric and Hesemeier 2002). While the challenge of developing an effective, reliable, and valid evaluation system is formidable (Kay and Knaack 2005; Nesbit and Belfer 2004), assessing effectiveness is critical if learning objects are to be considered a viable educational tool.

To date, the evaluation of learning objects has taken place predominantly at the development and design phase (Adams et al. 2004; Bradley and Boyle 2004; Maslowski and Visscher 1999; Vargo et al. 2003; Williams 2000). This kind of formative analysis, done while learning objects are created, is useful for developing easy to use learning objects, but the voice of the end user, the student who uses the learning object, is relatively silent.

A limited number of repositories have content experts, often educators, evaluate the quality of learning objects (Cafolla 2006; Krauss and Ally 2005; Schell and Burns 2002) after they have been developed. However, the number of evaluators is usually limited, the assessors have limited background in instructional design, and the end user does not enter the feedback loop in a significant way.

Until recently, learning objects were solely used in higher education. Therefore the majority of learning object evaluation has taken place in this domain (Haughey and Muirhead 2005; Kay and Knaack 2005, 2007a). Increased use of learning objects in the K-12 domain (e.g., Brush and Saye 2001; Clarke and Bowe 2006a, b; Kay and Knaack 2005; Lopez-Morteo and Lopez 2007; Liu and Bera 2005; Nurmi and Jaakkola 2006a) demands that the focus of evaluation shift, at least in part, to the needs of middle and secondary school students. The purpose of the current study was to examine a student–based learning object evaluation tool in middle and secondary school classrooms.

Literature review

Definition of learning objects

In order to develop a clear, effective metric, it is important to establish an acceptable operational definition of a "learning object". Original definitions focused on technological issues such accessibility, adaptability, the effective use of metadata, reusability, and standardization (e.g., Downes 2003; Littlejohn 2003; Koppi et al. 2005; Muzio et al. 2002; Nurmi and Jaakola 2006b; Parrish 2004; Siqueira et al. 2004). More recently, researchers are emphasizing learning qualities such as interaction and the degree to which the learner actively constructs knowledge (Baruque and Melo 2004; Bennett and McGee 2005; Bradley and Boyle 2004; Caws et al. 2006; Chenail 2004; Cochrane 2005; McGreal 2004; Kay and Knaack 2007a; Sosteric and Hesemeier 2002; Wiley et al. 2004).

While both technical and learning-based definitions offer important qualities that can contribute to the success of learning objects, evaluation tools focusing on learning are noticeably absent (Kay and Knaack 2007a). In order to address a clear gap in the literature on evaluating learning objects, a pedagogically focused definition of learning objects has been adopted for the current study based on a composite of previous definitions. Key factors emphasized included interactivity, accessibility, a specific conceptual focus, reusability, meaningful scaffolding, and learning. As indicated at the beginning of this paper, learning objects are operationally defined as "interactive web-based tools that support the learning of specific concepts by enhancing, amplifying, and/or guiding the cognitive processes of learners". Some examples selected by teachers for this study include learning objects designed to explore how students factors numbers, how integers work, how volume is calculated, exploring how tornado and hurricanes work, investigating the water cycle, and balancing chemical equations. To view specific examples of learning objects used by teachers in this study, see the links provided in Appendix A.

Theory underlying the evaluation of learning objects

While current methods used to evaluate learning objects are somewhat limited with respect to underlying learning theory (e.g., Buzzetto-More and Pinhey 2006; Gadanidis et al. 2004; Koohang and Du Plessis 2004; McGreal et al. 2004; Schoner et al. 2005), considerable speculation and discussion has taken place on the necessary attributes for developing effective assessment tools. Three key themes have emerged from these discussions: learning, quality or instructional design, and engagement.

Learning

Learning object research has addressed technical, instructional design issues in evaluation far more than issues based on pedagogy (Alonso et al. 2005; Jonassen and Churchhill 2004; Kay and Knaack 2005). This emphasis on design has resulted in a model of learning that is dated and largely behavioristic—content is presented, students are asked questions, and then evaluated and rewarded based on the content they remember (Friesen and Anderson 2004; Krauss and Ally 2005; Nurmi and Jaakkola 2006b). For the past 20 years, though, research in cognitive science suggests that students need to construct knowledge and actively participate in the learning process (e.g., Albanese and Mitchell 1993; Bruner 1983, 1986; Brown and Palinscar 1989; Chi and Bassock 1989; Collins et al. 1989; Vygotsky 1978) and within the last five years, several learning object theorists have advocated the use of a more constructivist-based metric (Baser 2005; Convertini et al. 2006; Gadanidis et al. 2004).

One way of indirectly examining the construction or building of knowledge is by measuring the amount and quality of interactivity in a learning object. Interactivity often defines the very nature of a learning object. While there is a tendency to view all interactivity as desirable, considerable debate reigns on finding key elements of effective interaction (Ohl 2001). Some learning objects simply require point and click progression through a series of pages that are passively read and digested. Others require direct manipulation of tools (e.g., sliders) requiring the user to test and evaluate "what-if" scenarios. Still others involve the presentation of simultaneous multimedia formats (e.g., vide, graphics, audio) to illustrate specific concepts. Van Merriënboer and Ayres (2005) speculate that interaction requiring a student to manipulate digital learning materials may be more motivating and stimulating. Lim et al. (2006) have proposed six different levels of interactivity including mouse pointing and clicking, linear navigation, hierarchical navigation, interacting with help, program-generated questions, and constructing or manipulating. Finally, Oliver and McLoughlin (1999) argue that, ideally, students who use learning objects should be making reasoned actions, engaging in personal meaning making, and integrating knowledge.

To date, interactivity has not been systematically integrated into the learning object evaluation process. However, there is some evidence that students believe that learning features of a learning object are more important than the technical features (Kay and Knaack 2005; 2007a).

Quality (instructional design)

For the purpose of this paper, the quality of a learning object refers to technical, design issues focusing on usability, as opposed to the learning issues discussed above. Evaluating the quality of learning objects is based on a wealth of research looking at the instructional design of digital materials and includes the following features: organization and layout (Calvi 1997; Madhumita and Kumar 1995; Mayer and Moreno 2002), learner control (Hanna et al. 1999; Kennedy and McNaught 1997; Scheiter and Gerjets 2007), multimedia in the form of animation, graphics, and audio (Gadanidis et al. 2003; Mayer and Moreno 2002; Sedig and Liang 2006), clear instructions to guide how to use a learning object and help features (Acovelli et al. 1997; Jones et al. 1995; Kennedy and McNaught 1997), feedback and assessment (Kramarski and Zeichner 2001; Zammit 2000), and theme (Akpinar and Hartley 1996; Harp and Mayer 1998). In spite of this well researched list of qualities that have been reported to affect software usability, summative evaluation tools rarely address the instructional design qualities of learning objects. It is more typical to collect open-ended, informal feedback without reference to specific instructional design characteristics that might enhance or reduce learning performance (e.g., Bradley and Boyle 2004; Kenny et al. 1999; Krauss and Ally 2005).

Cognitive load theory (Chandler and Sweller 1991; Kester et al. 2006; Van Gerven et al. 2006; Sweller 1988; Sweller et al. 1998) has been used to organize and explain the potential impact that the features of a learning object can have on performance. The main premise is that a typical user wants to minimize extraneous cognitive load (engaging in processes that are not beneficial to learning) and optimize germane cognitive load (engaging in processes that help to solve the problem at hand). Therefore, if the quality or instructional design of a learning object is sufficiently weak in one or more areas, the user spends more time on trying to use the object than on learning the concept at hand. Because the quality of learning objects is rarely addressed in the literature, little is known about how learning object design features affect cognitive load and ultimately how much is learned by the end user.

Engagement

In this study, engagement and motivation are used interchangeably, based on previous studies of learning objects (e.g., Lin and Gregor 2006; Oliver and McLoughlin 1999; Van Marriënboer and Ayres 2005). A number of authors believe that a high level of engagement or motivation is necessary for a learning object to be successful. Lin and Gregor (2006) suggest that engagement, positive affect, and personal fulfilment are key factors in the evaluation process. Oliver and McLoughlin (1999) add that learner self-efficacy is critical to promoting engagement in learning objects. Van Marriënboer and Ayres (2005) note that lower task involvement, as a result of reduced motivation, can result in a lower investment of cognitive effort. In summary, it is important to consider the degree to which a learning object engages students when evaluating effectiveness.

Previous approaches to evaluating learning objects

Considerable effort has been directed toward the evaluation of learning objects as they are being created (Adams et al. 2004; Bradley and Boyle 2004; Cochrane 2005; MacDonald et al. 2005; Nesbit et al. 2002; Vargo et al. 2003). Also known as formative assessment, this approach to evaluation typically involves a small number of participants being asked to test and use a learning object throughout the development process. Cochrane (2005) provides a good example of how this kind of evaluation model works where feedback is solicited from small groups at regular intervals during the development process. While formative evaluation is necessary for the development of learning objects that are well designed from a usability standpoint, this type of assessment does not address how well the learning object works in a real-world educational environment with actual students.

Qualitative analysis of learning objects is also prevalent in the evaluation literature in the form of interviews (Bradley and Boyle 2004; Kenny et al. 1999; Lin and Gregor 2006), written comments (Kay and Knaack 2005; Kenny et al. 1999; Krauss and Ally 2005), email responses (Bradley and Boyle 2004; MacDonald et al. 2005) and think-aloud protocols (Holzinger 2004; Krauss and Ally 2005). The majority of studies using a qualitative approach rely almost exclusively on descriptive data and anecdotal reports to assess the merits of learning objects. Furthermore, the reliability and validity of these informal qualitative observations have not been assessed (Bradley and Boyle 2004; Holzinger 2004; Kenny et al. 1999; Krauss and Ally 2005).

Quantitative efforts to evaluate learning objects have incorporated surveys (Bradley and Boyle 2004; Howard-Rose and Harrigan 2003; Krauss and Ally 2005), performance data (Adams et al. 2004; Bradley and Boyle 2004; Nurmi and Jaakola 2006a), and statistics recording use (Bradley and Boyle 2004; Kenny et al. 1999). The main concerns with the quantitative measures used to date are a lack of theory underlying measures and the absence of reliability and validity estimates.

A common practice employed to evaluate learning objects is to use multiple assessment tools (Bradley and Boyle 2004; Brown and Voltz 2005; Cochrane 2005; Kenny et al. 1999; Krauss and Ally 2005; Nesbit and Belfer 2004; Schell and Burns 2002; Schoner et al. 2005; Van Zele et al. 2003). This approach, which leads to triangulation of data analysis, should be encouraged. However, the multitude of constructs that have evolved to date do not provide a coherent model for understanding what factors contribute to the effectiveness of learning objects.

Methodological issues

At least six key observations are noteworthy with respect to methods used to evaluate learning objects. First, a wide range of learning objects have been examined, including drill-and-practice assessment tools (Adams et al. 2004) or tutorials (Nurmi and Jaakkola 2006a), video case studies or supports (Kenny et al. 1999; MacDonald et al. 2005), general web-based multimedia resources (Van Zele et al. 2003), and self-contained interactive tools in a specific content area (Bradley and Boyle 2004; Cochrane 2005). The content and design of a learning object need to be considered when examining quality and learning outcomes. For example, Cochrane (2005) compared a series of four learning objects based on general impressions of reusability, interactivity, and pedagogy and found that different groups valued different areas. In addition, Nurmi and Jaakkola (2005) compared drill-and-practice versus interactive learning objects and found the latter to be significantly more effective in improving overall test performance.

Second, even though a wide range of learning objects exist, the majority of evaluation papers focus on a single learning object (Adams et al. 2004; Bradley and Boyle 2004; Kenny et al. 1999; Krauss and Ally 2005; MacDonald et al. 2005). It is difficult to determine whether the evaluation tools used in one study generalize to the full range of learning objects that are available on the Internet. Third, while the number of studies focusing on the K to 12 population has recently increased (e.g., Brush and Saye 2001; Clarke and Bowe 2006a, b; Kay and Knaack 2005; Lopez-Morteo and Lopez 2007; Liu and Bera 2005; Nurmi and Jaakkola 2006a), most evaluation of learning objects has been done in the domain of higher education. Fourth, sampled populations tested in many studies have been noticeably small and poorly described (e.g., Adams et al. 2004; Cochrane 2005; Krauss and Ally 2005; MacDonald et al. 2005; Van Zele et al. 2003), making it challenging to extend any conclusions to a larger population.

Fifth, while most evaluation studies reported that students benefited from using learning objects, the evidence is based on loosely designed attitude assessment tools with no validity or reliability (Bradley and Boyle 2004; Howard-Rose and Harrigan 2003; Krauss and Ally 2005; Kenny et al. 1999; Lopez-Morteo and Lopez 2007; Schoner et al. 2005; Vacik et al. 2006; Van Zele et al. 2003; Vargo et al. 2003). Also, very few evaluation studies (e.g., Kenny et al. 1999; Kay and Knaack 2007a; Van Zele et al. 2003) use formal statistical analyses. The lack of reliability and validity of evaluation tools combined with an absence of statistical rigor reduce confidence in the results presented to date.

Finally, a promising trend in learning object evaluation research is the inclusion of measures to assess how well students perform (e.g., Adams et al. 2004; Bradley and Boyle 2004; Docherty et al. 2005; MacDonald et al. 2005; Nurmi and Jaakkola 2006a). Until recently, there has been little evidence to support the usefulness or pedagogical impact of learning objects. The next step is to refine current evaluation tools to determine which specific qualities of learning objects influence performance.

In summary, previous methods used to evaluate learning objects have offered extensive descriptive and anecdotal evaluations of single learning objects, but are limited with respect to sample size, representative populations, reliability and validity of data, and the use of formal statistics. Recent evaluation efforts to incorporate learning performance should be encouraged in order to advance knowledge of learning object features that may influence learning.

Current approach to evaluating learning objects

Theoretical model

The model used to support the evaluation tools in this study was based on a (a) thorough review of the literature on learning objects (see above) and (b) recent feedback from a similar evaluation tool developed by Kay and Knaack (2007a). Consequently, three key constructs were developed for the quantitative survey and included learning, quality, and engagement (see Appendix B). The learning construct referred to a student’s perception of how much he/she learned from using the learning object. The quality construct referred to the design of the learning object and included the following key instructional design features identified by Kay and Knaack (2007a): help features, clarity of instructions, ease of use, and organization. Finally, the engagement construct examined how involved a student was with respect to using a learning object. Estimates of all three constructs were supplemented by written comments that students made about what they liked and did not like about the learning object. The qualitative coding rubric used in the current study incorporated learning benefits and a full range of instructional design features (see Table 2). Finally, learning performance was incorporated into the evaluation system.

Purpose

The purpose of this study was to explore a student-focused, learning-based approach for evaluating learning objects. Based on a detailed review of studies looking at the evaluation of learning objects, the following steps were followed:

1. a large sample was used;
2. a wide range of learning objects were tested;
3. the design of the evaluation tools was based on a thorough review and categorization of the learning object literature and instructional design research;
4. reliability and validity estimates were calculated;
5. formal statistics were used where applicable;
6. both qualitative and quantitative data were collected, systematically coded, and analyzed;
7. measures of learning performance were included; and
8. evaluation criteria focused on the end user perceptions and not those of the learning object designers.

Method

Sample

Students

The student sample consisted of 1,113 students (588 males, 525 females), ranging from 10 to 22 years of age ($M = 15.5$, $SD = 2.1$), from both middle ($n = 263$) and secondary schools ($n = 850$). The population base spanned three separate boards of education, six middle schools, 15 secondary schools, and 33 different classrooms. The students were selected through convenience sampling and had to obtain signed parental permission to participate.

Teachers

The teacher sample consisted of 33 teachers (12 males, 21 females), with 0.5–33 years of teaching experience ($M = 9.0$, $SD = 8.2$), from both middle ($n = 6$) and secondary schools ($n = 27$). Most teachers taught math (48%) or science (45%). A majority of the teachers rated their ability to use computers as strong or very strong (76%) and their attitude toward using computers as positive or very positive (89%). In spite of the high ability and positive attitude, only six of the teachers used computers in their classrooms more than once a month. Teachers from each board of education were notified electronically by a educational coordinator that a study on learning objects was taking place and asked if they would like to participate.

Learning objects

In order to simulate a real classroom as much as possible, teachers were allowed to select any learning object they deemed appropriate for their curriculum. As a starting point, they were introduced to a wide range of learning objects located at the LORDEC website (http://www.education.uoit.ca/lordec/collections.html). Sixty percent of the teachers selected learning objects from the LORDEC repository—the remaining teachers reported that they used Google. A total of 48 unique learning objects were selected covering concepts in biology, Canadian history, chemistry, general science, geography, mathematics, and physics (see Appendix A for the full list).

Procedure

Teachers from three boards of education were emailed by an educational coordinator and informed of the learning object study. Participation was voluntary and a subjects could withdraw from the study at any time. Each teacher received a half day of training in November on how to choose, use, and assess learning objects (see http://www.education.uoit.ca/lordec/lo_use.html for more details on the training provided). They were then asked to use at least one learning object in their classrooms by April of the following year. Email support was available throughout the duration of the study. All students in a given teacher's class used the learning object that the teacher selected. However, only those students with signed parental permission forms were permitted to fill in an anonymous, online survey about their use of the learning object. In addition, students completed a pre- and post-test based on the content of the learning object.

Data sources

Student survey

After using a learning object, students completed the Learning Object Evaluation Scale for Students (LOES-S; see Appendix B) to determine their perception of (a) how much they learned (learning construct), (b) the quality of the learning object (quality construct), and (c) how much they were engaged with the learning object (engagement construct). Descriptive statistics for the LOES-S are presented in Table 1.

Student comments

Students were asked to comment on what they liked and disliked about the learning object (Appendix B—questions 13 and 14). These open-ended items were organized according to the three main constructs identified in the literature review (learning, quality, and engagement) and analyzed using the coding scheme provided in Table 2. This coding scheme (Kay and Knaack 2007a) was used to categorize 1922 student comments. Each comment was then rated on a five-point Likert scale (-2 = very negative, -1 = negative, 0 = neutral, 1 = positive, 2 = very positive). Two raters assessed all comments made by students based

Table 1 Description of student Learning Object Evaluation Scales (LOES-S)

Scale	Number of items	Possible range	Actual range observed	Internal reliability
LOES-S				
Learn	5	5–25	12.6–20.6	$r = 0.89$
Quality	4	4–20	10.9–18.3	$r = 0.84$
Engage	3	3–15	7.1–12.8	$r = 0.78$

Table 2 Coding scheme to categorize student comments about learning objects

Category label	Criteria
Learning	
Challenge	Refers to the ease/difficulty of the concepts being covered. Basically whether the content level of the LO matched the student's cognitive level/ understanding
	Code "it was easy" in here, but not "it was easy to use"
Learn	Student comments about a specific or general learning/teaching issue involved in using the LO
Visual	The student mentions a visual feature of the LO that helped/inhibited their learning
Engagement	
Compare	Student compares LO to another method of learning
Engage	Student refers to program as being OR not being fun/enjoyable/engaging/ interesting
Technology	The student mention a technological issue with respect to using the LO
Quality	
Animate	Refers to quality of animations/moving pictures
Audio	Refers to some audio/sound aspect of the learning object
Easy	Refers to clarity of instructions or how easy/hard the LO was to use. It does not refer to how easy/hard the concept was to learn
Graphics	Refers to static picture or look of the program (e.g., colours)
Help	Refers specifically to help/hints/instructions/feedback provided by the LO
Interactive	Student refers to some interactive part feature of the LO
Control	Refers to student control of choice/pace in using the LO
Organization/Design	Refers to quality of organization/design or the LO
Text	Refers to quality/amount of text in LO
Theme	Refers to overall/general theme or CONTENT of LO

on category and rating value. Comments where categories or ratings were not exactly the same were shared and reviewed a second time by each rater. Using this approach, an inter-rater reliability of 99% was attained for categories and 100% for the rating values.

Student performance

Students completed a pre- and post-test created by each teacher based on the content of the learning object used in class. Questions for pre- and post-test were identical in form, but differed in the raw numbers used. The type of questions asked varied according to the goal of the specific learning objects. Some tests focussed primarily on factual knowledge while others assess higher order thinking focussing on "what-if" scenarios. The measure was used to determine student performance. Because of the wide range of learning objects used, it was not possible to assess the validity of this test data.

Teacher survey

After using a learning object, each teacher completed the Learning Object Evaluation Scale for Teachers (LOES-T) to determine their perception of (a) how much their students learned (learning construct), (b) the quality of the learning object (quality construct), and (c) how much their students were engaged with the learning object (engagement construct). Data from the LOES-T showed low to moderate reliability (0.63 for learning construct, 0.69 for learning object quality construct, and 0.84 for engagement construct), good construct validity using a principal components factor analysis. See Kay and Knaack (2007b) for a detailed of the teacher-based learning object scale.

Data analysis

A series of analyses were run to assess the reliability and data generated by the LOES-S for students. These included:

(1) internal reliability estimates (reliability);
(2) a principal component factor analysis for Student LOES-S (construct validity);
(3) correlations among learning object evaluation constructs within the LOES-S scales (construct validity);
(4) correlation between LOES-S and LOES-T constructs (convergent validity);
(5) correlation between LOES-S and computer comfort level (convergent validity);
(6) correlations between coded student comments and LOES-S constructs (face validity);
(7) correlation between learning performance and LOES-S constructs (predictive validity).

Results

Internal reliability

The internal reliability estimates for the LOES-S constructs based on Cronbach's α were 0.89 (Learning), 0.84 (Quality), and 0.78 (Engagement)—see Table 1. These moderate-to-high values are acceptable for measures in the social sciences (Kline 1999; Nunnally 1978).

Construct validity

Principal component analysis

While the literature review suggests that constructs related to learning, quality, and engagement may exist, the evidence provided is too weak to support the use of a confirmatory factor analysis. Therefore, a principal components analysis was done to explore whether the three learning object constructs (learning, quality, and engagement) in the LOES-S formed three distinct factors. Since all communalities were above 0.4 (Stevens 1992), the principal component analysis was deemed an appropriate exploratory method (Guadagnoli and Velicer 1988). Orthogonal (varimax) and oblique (direct oblimin) rotations were used, given that the correlation among potential strategy combinations was unknown. These rotational methods produced identical factor combinations, so the results from the varimax rotation (using Kaiser normalization) are presented because they simplify the interpretation of the data (Field 2005). The Kaiser–Meyer–Olkin measure of sampling adequacy (0.937) and Bartlett's test of sphericity ($p < .001$) indicated that the sample size was acceptable.

Table 3 Varimax rotated factor loadings on Learning Object Evaluation Scale for Students (LOES-S)

Scale item	Factor 1	Factor 2	Factor 3
S-Learn 1—Interact	.786		
S-Learn 2—Feedback	.737		
S-Learn 3—Graphics	.621		
S-Learn 4—New Concept	.764		
S-Learn 5—Overall	.728		
S-Quality 6—Help	.563	.514	
S-Quality 7—Instructions		.841	
S-Quality 8—Easy to use		.817	
S-Quality 9—Organized		.719	
S-Engagement 10—Theme			.810
S-Engagement 11—Motivating	.440		.689
S-Engagement 12—Use again			.686

Factor	Eigenvalue	PCT of VAR	CUM PCT
1	6.70	55.8	55.8
2	1.11	9.3	65.1
3	0.70	5.9	71.0

The principal components analysis was set to extract three factors (Table 3). The resulting rotation corresponded well with the proposed learning object evaluation constructs with two exceptions. Factor 1, the learning construct, included the five predicted scale items, but also showed relatively high loadings on one of the quality construct items (Item 6—help features being useful) and one of the engagement construct items (Item 11—motivational value). Overall, the structure was consistent with previous research (Kay and Knaack 2007a) and the proposed grouping of scale items listed in Appendix B.

Correlations among LOES-S constructs

The correlations between the learning construct and the quality ($r = .68 \pm 0.03$, $p < .001$, $n = 934$) and engagement ($r = .74 \pm 0.03$, $p < .001$, $n = 1012$) constructs were significant, as was the correlation between the engagement and quality construct ($r = .64 \pm 0.04$, $p < .001$, $n = 963$). Shared variances, ranging from 40% to 54% were small enough to support the assumption that each construct measured was distinct.

Convergent validity

Correlation between LOES-S and LOES-T constructs

Mean student perceptions of learning, quality, and engagement correlated significantly with teacher perceptions of learning, quality, and engagement, respectively. In addition, correlations among different constructs were also significant. Correlations ranged from 0.25 to 0.47, indicating a moderate degree of consistency between student and teacher evaluations of learning objects using the LOES-S and LOES-T scales (Table 4).

Table 4 Correlations among LOES-S and LOES-T constructs ($n = 63$)

	S-Learn		S-Quality		S-Engage	
	r	CI	r	CI	r	CI
T-Learn	0.47***	0.26–0.65	0.47***	0.26–0.65	0.44***	0.22–0.63
T-Quality	0.45***	0.23–0.64	0.45***	0.23–0.64	0.43***	0.21–0.62
T-Engagement	0.25*	0.00–0.47	0.33**	0.09–0.54	0.39*	0.16–0.58

CI = Confidence interval

* $p < .05$ (2-tailed)

** $p < .01$ (2-tailed)

*** $p < .001$ (2-tailed)

Correlation between student computer comfort level and LOES-S constructs

Computer comfort level based on a 3-item scale (Kay and Knaack 2007a) was significantly correlated with the learning ($r = .27 \pm 0.05$; $p < .001$, $n = 1022$), quality ($r = .26 \pm 0.06$; $p < .001$, $n = 976$), and engagement constructs ($r = .32 \pm 0.05$; $p < .001$, $n = 1079$). The more comfortable that a student was with the computers, the more likely he/she would rate learning, quality, and engagement of a learning object higher.

Correlation between student comments and LOES-S constructs

Recall that an average rating score based on a five-point Likert scale was calculated for each comment made by a student (refer Table 2 for comment categories). The LOES-S learning construct showed significant correlations with average student ratings of comments about learning ($r = 0.27 \pm 0.07$, $p < .001$, $n = 696$), challenge level ($r = 0.17 \pm 0.07$, $p < .001$, $n = 696$), and visual aids ($r = 0.11 \pm 0.07$, $p < .005$, $n = 696$). The LOES-S quality construct showed very small, but significant correlations with average student ratings of comments about learning objects being easy to use ($r = 0.09 \pm 0.08$, $p < .05$, $n = 663$), quality of help given ($r = 0.09 \pm 0.08$, $p < .05$, $n = 663$), and the quality/amount of text in a learning object ($r = 0.09 \pm 0.08$, $p < .05$, $n = 663$). Finally, the LOES-S engagement construct showed a significant correlation with average student ratings of comments made about engagement ($r = 0.21 \pm 0.07$, $p < .001$, $n = 742$).

Predictive validity

Correlation between learning performance and LOES-S constructs

Learning objects that were used for reviewing subject matter already taught were not included in the learning performance analysis to reduce the potential influence of previous teaching strategies. Learning performance (percent change from the pre- to the post-tests) for classes where a learning object was not used for review ($n = 273$), was significantly and positively correlated with the learning ($r = .18 \pm 0.12$; $p < .01$, $n = 254$), quality ($r = .22 \pm 0.12$; $p < .005$, $n = 242$), and engagement constructs ($r = .10 \pm 0.12$; $p < .005$, $n = 273$). In other words, higher scores on student perceptions of learning, learning object quality, and engagement were associated with higher scores in learning performance, although this effect is relatively small.

Discussion

The purpose of this study was to systematically investigate a student-focused approach for evaluating learning objects, based on three prominent themes that appeared in previous research: learning, quality, and engagement. Key issues addressed were sampling of students, range of learning objects assessed, reliability, validity, using formal statistics where applicable, incorporating both qualitative and quantitative feedback, and student performance. Each of these issues will be discussed in turn.

Sample population and range of learning objects

The population in this study was a large sample of middle and secondary school students ($n = 1113$) spread out over three school districts and 15 schools. This type of sampling is needed to build on previous small-scale research efforts in order to provide in-depth analysis and confidence regarding specific learning object features that affected learning.

The sizable number ($n = 48$) of learning objects tested is a significant departure from previous studies and offers evidence to suggest that the usefulness of the LOES-S extends beyond a single learning object. While it is beyond the scope of this paper to compare specific types of learning objects used, it is reasonable to assume that the LOES-S is a credible tool for evaluating a wide range of learning objects.

Reliability

The internal reliability estimates (0.78–0.89) for the learning object constructs in the LOES-S were good (Kline 1999; Nunnally 1978), as was the inter-rater reliability (99%) of the categories and ratings used to assess student comments. Less than 25% of the 25 formal evaluation studies reviewed for this paper (Baser 2005; Kay and Knaack 2005; Kong and Kwok 2005; Liu and Bera 2005; Vargo et al. 2003; Windschitl and Andre 1998) offered reliability statistics, yet it is argued that reliability is a fundamental element of any evaluation tool and should be calculated for future research studies, if the sample size permits.

Validity

Only two of the 25 studies reviewed for this paper offer validity estimates (Kay and Knaack 2007a; Nurmi and Jaakkola 2006a). Therefore, it is prudent to address validity in future learning object evaluation tools. Four types of validity were considered in this paper: face, construct, convergent, and predictive.

Face validity

Face validity was supported by the close alignment between the three proposed LOES-S constructs (learning, quality, and engagement) and those features identified as central in the comprehensive review of the literature completed for this study. Aligning scale constructs with a systematic analysis of previous theory is important if face validity is to be established. Face validity was also partially confirmed by the significant correlations among student comments and the three LOES-S subscales. However, correlations were modest (between .21 and .27) for learning and engagement constructs and low ($r = 0.09$) for quality. These findings indicates that more qualitative data, perhaps in the form of interview and focus groups, may be needed in developing scale items that more accurately reflect actual student perceptions. The result may also reflect the variability in responses that comes with examining a wide range of learning objects.

Construct validity

The principal components analysis revealed three relatively distinct learning object constructs that were consistent with the theoretical framework proposed by previous learning object researchers and instructional design specialists. However, two exceptions were noted. First, quality of help (item 6 in Appendix B) showed high communality with both learning and quality constructs. This result might be explained in part by the specific focus of help offered by a learning object. Sometimes help is offered to make the learning object easier to use. Other times help is given to support the actual learning of a concept. Item six (Appendix B) might need to be modified to reflect the use of help in facilitating the use of the actual learning object.

The second exception involved the perceived motivation value of a learning object (item 10, Appendix B) which loaded relatively high on both learning and engagement constructs. One interpretation of this finding is that learning objects that effectively support learning are probably more motivating to students. Exploring the source of motivation is a necessary next step in improving the LOES-S scale.

While it is beneficial to isolate discrete constructs of a learning object in order to identify potential strengths and weaknesses, the reality may be that these constructs interact and mutually influence each other when actual learning occurs. For example, a learning object that is not effective at promoting learning could have a negative impact on perceived engagement. Furthermore, a learning object that is particularly difficult to use may frustrate students and impede learning and limit engagement. Finally, highly engaging learning objects may focus students and this may lead to more effective learning. These proposed interactions are partially reflected in the relatively high correlations among learning object constructs (0.63–0.74). However, shared variance of only 40% to 54% indicates that learning, quality, and engagement constructs were also distinct.

Convergent validity

Convergent validity was supported by two tests. First, correlations between student estimates of learning, quality, and engagement were significantly correlated with teacher estimates of these same constructs. The correlations, though, were not high with a typical shared variance of about 20%. However, this result might be expected given that teachers and students may have different perceptions on what constitutes learning, quality, and engagement. Therefore, while student and teacher constructs do converge, the modest correlations underline one of the main premises of this paper, namely the need for obtaining student input.

The second test of convergent validity looked at correlations among the three LOES-S constructs and student computer comfort level. It was predicted that students who were more comfortable with computers would rate learning objects more highly in terms of learning, quality, and motivation. This prediction was supported by the low (0.26–0.32), but significant correlation estimates observed. The modest impact of computer comfort level may be partially explained by the relative ease of use of most learning objects. Students who are uncomfortable with computers may experience minor, but not excessive challenges when interacting with tools that are designed to be simple to use. Further research is needed to explore the impact of computer comfort.

Predictive validity

It is reasonable to predict that learning objects that are rated highly in terms of learning, quality, and/or engagement should result in better learning performance. In other words, if a student perceives a learning object as a high quality, effective learning tool that is engaging, we would expect him/her to perform better in a pre-post test situation. Significant, but small (0.10–0.22), correlations between the percent change in pre-post test scores and the LOES-S learning, quality, and engagement constructs supported these predictions. One might expect these correlations to be higher if the LOES-S is to be an effective assessment tool, however, learning is a complex process involving numerous variables including instructional wrap, student ability in a subject area, student attitude toward a subject, gender, and time using the learning object. The challenges and problems of education are always more complex than technology alone can solve, therefore, modest correlations between key learning object constructs and learning performance are probably to be expected.

Implications for education

The main purpose for this paper was to develop a reliable, valid student-based evaluation tool for assessing learning objects. However, there are several implications for education. First, it is prudent to gather student input when using learning objects and other technologies in the classroom. While teacher and student assessment of learning benefits, quality, and engagement are consistent with each other, they only share 20% common variance. It is through student feedback that these tools and the instructional wrap that supports them can be improved.

Second, the evaluation tool in this study offers some guidance on key features to focus on when selecting a learning object. Learning features such as interactivity, clear feedback, and graphics or animations that support learning are desirable, as are design qualities such as effective help, clear instructions, transparency of use and organization. It is probably more challenging for an educator to understand what engages a student, although overall theme can impact positively or negatively on learning.

Finally, it is important to remember the low but significant correlations among student evaluations of learning, quality, and engagement and learning performance. No technology will transform the learning process. Learning objects are simply tools used in a complex educational environment where decisions on how to use these tools may have considerably more import than the actual tools themselves.

Caveats and future research

This study was designed with careful attention paid to the details of theory and methodology. An attempt was made to develop a learning object evaluation tool that was sensitive to key issues researched over the past 10 years. A three-prong model was developed and tested on a large sample, using a wide range of learning objects. Nonetheless, there are several caveats that should be addressed to guide future research.

First, student ability was not examined and may have an impact on the success of any learning tool, let alone a learning object. In other words, students who like a subject may be more open to new ways of learning concepts, whereas students who are struggling may find the use of a learning object distracting and challenging. Assessing student ability might provide further clarity in future research endeavors.

Second, instructional wrap or strategies employed to incorporate learning objects in the classroom probably have an impact on the effectiveness. For example, a learning object used exclusively as a motivational or demonstration tool, might not have as much an effect as a learning object used to teach a new concept. While some effort was made to assess how the learning object was used (e.g., for review), a more detailed analysis of instructional wrap could offer additional understanding of learning object usefulness.

Third, more directed and through qualitative analysis is needed to assess the design qualities of learning objects. The open-ended approach used in the current study generated a wide range of responses and these responses could now be used to gather more in depth data. For example, students could be asked what features specifically supported and detracted from their learning and how they would design the learning object to be more effective.

Fourth, tests used to assess performance in this study, were created on an ad hoc basis, by individual teachers. No effort was made to standardize measures or to assess reliability and validity. Higher quality learning performance tools should increase the precision of results collected.

Finally, it would be extremely beneficial to compare systematic external evaluations of learning objects by experts with student evaluations and performance. We could then begin to assess whether design efforts and certain types of learning objects have their intended impact.

Appendix A List of learning objects used in the study

Collection	Level	Name of learning object	Web address	Access
AAA Math	MS	Geometric Facts	http://www.eyepleezers.com/aaamath/geo.htm#topic1	Open
BBC	MS	Rocks and Soil	http://www.bbc.co.uk/schools/scienceclips/ages/7_8/rocks_soils.shtml	Open
Independent	MS	Space Trading Cards	http://amazing-space.stsci.edu/resources/explorations/trading/	Open
Learn Alb	MS	Probability	http://www.learnalberta.ca/content/mesg/html/math6web/math6shell.html?launch=true	Open
Learn Alb	MS	Volume and Displacement	http://www.learnalberta.ca/content/mesg/html/math6web/lessonLauncher.html?lesson=m6lessonshell15.swf&launch=true	Open
NLVM	MS	Factor Trees	http://nlvm.usu.edu/en/nav/frames_asid_202_g_2_t_1.html	Open
NLVM	MS	Fractions—Equivalent	http://nlvm.usu.edu/en/nav/frames_asid_105_g_3_t_1.html	Open
NLVM	MS	Fractions—Multiply	http://nlvm.usu.edu/en/nav/frames_asid_105_g_3_t_1.html	Open
NLVM	MS	How High	http://nlvm.usu.edu/en/nav/frames_asid_275_g_3_t_4.html	Open

Appendix A continued

Collection	Level	Name of learning object	Web address	Access
PBS Kids	MS	Make a Match	http://pbskids.org/cyberchase/games/equivalentfractions/	Open
TLF	MS	Integer Cruncher	http://www.thelearningfederation.edu.au/tlf2/	Closed
TLF	MS	Square Pyramids	http://www.thelearningfederation.edu.au/tlf2/	Closed
TLF	MS	Triangular Pyramids	http://www.thelearningfederation.edu.au/tlf2/	Closed
Anne Frank	HS	Anne Frank the writer	http://www.ushmm.org/museum/exhibit/online/af/htmlsite/	Open
Article 19	HS	Ohm Zone	http://www.article19.com/shockwave/oz.htm	Open
Bio Project	HS	Online Onion Root Tips	http://www.biology.arizona.edu/Cell_bio/activities/cell_cycle/cell_cycle.html	Open
Creative Chem	HS	Creative Chemistry	http://www.creative-chemistry.org.uk/gcse/revision/equations/index.htm	Open
Discovery	HS	*Weather Extreme: Tornado*	http://dsc.discovery.com/convergence/tornado/tornado.html	Open
DNA Int	HS	Gel electrophoresis	http://www.dnai.org/b/index.html	Open
FunBased	HS	Classic Chembalancer	http://funbasedlearning.com/chemistry/chemBalancer/	Open
Gizmos	HS	Balancing Chemical Reactions	http://www.explorelearning.com/	Open
Independent	HS	Congruent Triangles	http://argyll.epsb.ca/jreed/math9/strand3/3203.htm	Open
Independent	HS	Life in Shadows	http://www.ushmm.org/museum/exhibit/online/hiddenchildren/	Open
Independent	HS	Metals in Aqueous Solutions	http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/animationsindex.htm	Open
Independent	HS	Ripples of genocide	http://www.ushmm.org/museum/exhibit/online/congojournal/	Open
Independent	HS	Triangle Centres	http://www.geom.uiuc.edu/~demo5337/Group2/trianglecenters.html	Open
Learn Alb	HS	Ammeters and Voltmeters	http://www.learnalberta.ca/	Closed
Learn Alb	HS	Binomial distribution	http://www.learnalberta.ca/content/meda/html/binomialdistributions/index.html?launch=true	Open
Learn Alb	HS	Multiplying and Dividing Cells	http://www.learnalberta.ca/	Closed
Learn Alb	HS	*The Exponential Function*	http://www.learnalberta.ca/content/meda/html/exponentialfunction/index.html?launch=true	Open
NLVM	HS	Algebra Balance Scales	http://nlvm.usu.edu/en/nav/frames_asid_201_g_4_t_2.html?open=instructions	Open
PBS	HS	Structure of Metals	http://www.pbs.org/wgbh/nova/wtc/metal.html	Open
PHET	HS	Energy Skate Park	http://phet.colorado.edu/simulations/energyconservation/energyconservation.jnlp	Open
Shodor	HS	Maze Game	http://www.shodor.org/interactivate/	Open
TLF	HS	Alpha, Beta, Gamma of Radiation	http://www.thelearningfederation.edu.au/tlf2/	Closed
TLF	HS	Measuring: Similar Shapes	http://www.thelearningfederation.edu.au/tlf2/	Closed
TLF	HS	Mobile Phone Plans	http://www.thelearningfederation.edu.au/tlf2/	Closed

Appendix A continued

Collection	Level	Name of learning object	Web address	Access
TLF	HS	Reading Between the Lines	http://education.uoit.ca/lordec/lo/L80/LV5536/	Open
TLF	HS	Squirt: Proportional relationships	http://www.thelearningfederation.edu.au/tlf2/	Closed
UOIT	HS	Capillary Fluid Exchange	http://education.uoit.ca/EN/main/151820/151827/research_teach_locollection.php	Open
UOIT	HS	Charging an Electroscope	http://education.uoit.ca/EN/main/151820/151827/research_teach_locollection.php	Open
UOIT	HS	Relative Velocity	http://education.uoit.ca/EN/main/151820/151827/research_teach_locollection.php	Open
UOIT	HS	Slope of a Line	http://education.uoit.ca/EN/main/151820/151827/research_teach_locollection.php	Open
UOIT	HS	Transformation of Parabola	http://education.uoit.ca/EN/main/151820/151827/research_teach_locollection.php	Open
UW Madison	HS	Wild Weather	http://cimss.ssec.wisc.edu/satmet/modules/wild_weather/index.html	Open
Waterloo	HS	Waterloo: Hydrologic Cycle	http://www.region.waterloo.on.ca	Open
WISC Online	HS	Periodic table	http://www.wisc-online.com/objects/index_tj.asp?objid=SCI202	Open
Zona Land	HS	Equation of a Line	http://id.mind.net/~zona/mmts/functionInstitute/linearFunctions/lsif.html	Open

Appendix B Learning object evaluation survey—students

	Strongly disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly agree 5
Learning					
1. Working with the learning object helped me learn	1	2	3	4	5
2. The feedback from the learning object helped me learn	1	2	3	4	5
3. The graphics and animations from the learning object helped me learn	1	2	3	4	5
4. The learning object helped teach me a new concept	1	2	3	4	5
5. Overall, the learning object helped me learn	1	2	3	4	5
Quality					
6. The help features in the learning object were useful	1	2	3	4	5
7. The instructions in the learning object were easy to follow	1	2	3	4	5
8. The learning object was easy to use	1	2	3	4	5
9. The learning object was well organized	1	2	3	4	5

Appendix B continued

	Strongly disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly agree 5
Engagement	1	2	3	4	5
10. I liked the overall theme of the learning object	1	2	3	4	5
11. I found the learning object motivating	1	2	3	4	5
12. I would like to use the learning object again	1	2	3	4	5
13. What, if anything, did you LIKE about the learning object?					
14. What, if anything, did you NOT LIKE about the learning object?					

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